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STUDY OF CUSTOMISED COMPOSITE LAMINATED SHIMS USED IN COMBAT AIRCRAFT STRUCTURAL ASSEMBLY

SANJAY KUMAR[1] & DR. P. SELVARAJ[2]

[1]*Aircraft Research & Design Centre, Hindustan Aeronautical Limited, Bangalore, India*

[2]*Aeronautical Development Agency, Ministry of Defence, Bangalore, India*

ABSTRACT

Modern Combat Aircraft uses Advance carbon Pre-impregnated composite material for primary structures like Fuselage and wing for weight reduction, high fatigue strength and better design performance including stealth feature. Composite materials pose manufacturing challenges to achieve outer aerodynamic and inner contour within design values. Composite parts are made by layer build-up method with ply orientation of 0, 45 & 90 deg as shown in Figure 3. They show more variation and waviness at non-tool surface after autoclave curing and de-molding process. At the assembly stage, gaps can go up to 1.5-1.8 mm between sub-structure and skin. An aircraft primary structural assembly of wing and Fuselage require customized shims to fill gaps between structural components in the airframe that arise due to manufacturing process variation adding up across large contoured and complex structures. These shims, whether liquid or solid, are necessary to eliminate gaps to maintain design performance including fuel tight joints, and efficient fasteners joints. Various shims used in the aircraft industry are mentioned in Table 2, which are required to meet aircraft outer contour for aerodynamic efficiency and also to prevent fuel leak from the wing and fuselage assembly and to have fastener joint efficiency. Currently, gap shimming is a time-consuming process, these amounts to significant delays in production, with much of the time being spent in the shim preparation and installation which is of a considerable percentage of the critical path of the aircraft assembly. In this paper, the objective is to bring out a scientific study of shimming process based on process learning and prior data on variation and elicit gap distributions from historical data on prototypes aircraft built. The study has focused on Data from Coordinate Measurement Machine stage and shim prediction after CMM stage. The paper brings out the study on the existing shimming process and presents an existing model and further improvement for an efficient liquid and solid shimming system. The shimming process improvement will ensure better assembly quality and joint efficiency. The typical part joining process shown Figure 7 in the aircraft industry, assembly is made through drilling, followed by fastening. The typical tolerances for part tooling hole location in aircraft assembly are + 0.2 to -0.2 mm. The data have been collected for gaps measured by Feeler gauge between one of the composite spar of Combat aircraft wing and skin which is shown in Figure 8. It is known from Fiureg 9, that gap values are different on top and bottom flange due to Tool design and manufacturing process.

***KEYWORDS**:Shims, Solid Shims, Liquid Shim, Assembly, Fastening, Gap, De-lamination, Integral Fuel Tank, Fighter Aircraft, Flight Safety, Contour, Aerodynamic Surface & Layup*

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INTRODUCTION

The Combat aircraft studied is a four plus generation aircraft uses over 90% surface area is made of Advance composites material where 60% Fiber and 40%epoxy resin by weight. Composite materials are ideal for

structural applications where high strength-to-weight and high stiffness-to-weight ratios are required. Aircraft is typically weight sensitive structure in which composite materials can be cost effective when the full advantage of composite materials are utilized. Advance Composite manufacturing is increasingly becoming a data-rich endeavour, where challenges are to find out the solution of shimming process in assembly and produce assembly to meet design specifications. The manufacturing processes require precision control of the Outer Mold line (OML). The design of the wing assembly requires a shim gap between the assembled metallic, composite substructure and the mating Inner Mold Line (IML) composite skins. The current method for shimming in the wing requires the application and bonding of liquid shim and solid shims on to the spar top and bottom flanges are shown in figure 6 and skin inner surface. The solid shims are made of composite and, a liquid shim is prepared out of HYSOL EA934 and Al. powder product. The property of prepared liquid shim is given in Table 3. The problem with this shimming process is that it is very time consuming and is being customized at the assembly stage to fill up the measured gap. It is completely done manually, where the liquid shim is applied on the sub-structure through manual spread by plastic Spatula to cover the surface. This method is proving difficult to maintain a constant thickness of the cured shim. The process is messy and required extensive rework in many cases. Aircraft manufacturing covers the whole area of part design, NC-machining, sheet metal forming and manufacturing of carbon fiber components, whereas aircraft assembly concerns the assembly of the airframe from parts to sub-structures to a final airframe. Product prerequisites for airframe assembly are challenging. The most important demand is to have high fatigue resistance, as the consequences of fatigue in aerospace applications can be devastating. The wing is filled with fuel; it must also be fuel-tight. The assembly process is basically carried out by drilling holes followed by fastening. The joining elements used in the aircraft assemblies are special titanium fasteners. Prior to starting hole drilling and fasteners installation, it is important to check joint for the gap. Hence gaps are measured and shims are used for gap greater than 0.8mm. If the gap is more than 0.8 mm then solid and liquid shim and gap till 0.8mm only liquid shims. The shim model is shown in table 4. In detail a typical airframe assembly process follows the following sequence

- Pre-assembly
- Drilling
- Temporary fastening
- Debarring
- Sealant application
- Fastening

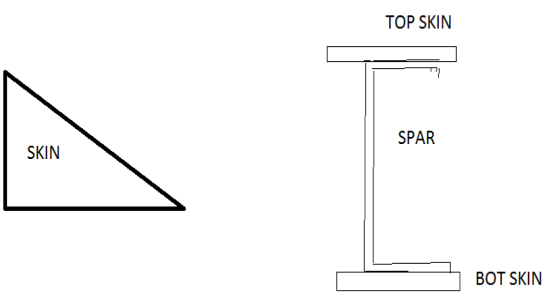

Figure 1: Spar Assembly Wing Skin

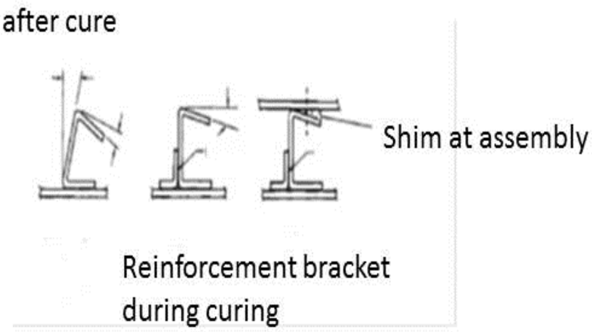

Figure 2: Shims Requirement at Different Stages of the Assembly Process

OBJECTIVE

The study is to understand the existing process which is being followed at manufacturing and wing assembly department while building combat aircraft wing assembly. The research effort is to develop an efficient and productive shimming system. This process shall pin-point the inefficiencies in the current shimming process and outline an ideal state process. This paper has brought out shimming process technology and shimming requirements. Identification of existing technologies related to liquid shim, sealant, or adhesive dispense and other associated shimming tasks. Identify potential system solutions for incorporation into a specification. Study the feasibility to use non-contact metrology technology like developing a fixture where parts can be checked before passing to the assembly by locating the structure and validate the surface profile before and after shim installation. Even explore the inspection of parts for a gap through tooling aide before assembly stage, which could later be used to evaluate the tool's ability to release from the structure after the shim has cured, tool locating techniques, and OML control tolerances achievable with no additional processing of the cured shim.

MATERIAL AND METHODS

Shims are made of AS4 epoxy resin of 60% and 40% unidirectional and bidirectional pre-impregnated carbon fiber. Lay up is done as per the design recommended fiber orientation as shown in figure 4. The manufacturing sequence is mentioned in figure. Lay up the stack is auto clave cured. Cured laminate in the sheet form is de-molded and inspected. Laminated solid shim is suited on assembly and customized in shape form as per requirement. The composite material used is AS4, 914 resin systems having cure temp 177 deg Celsius temperature. This is thermosetting epoxy resin shown in below Table-1.

Table 1: Epoxy Resin Properties

Matrix Type	Tack	Thermal Stability	Cure Temp	Cure Pressure	Void Content	cost
Epoxy	Excellent	180 ^{o} F	177 ^{o} C	100 psi	low	low

Thermosetting resin falls in the category of polymer matrix composites. There is enough data that epoxy resin is used up to service temperature up to 100 deg C.

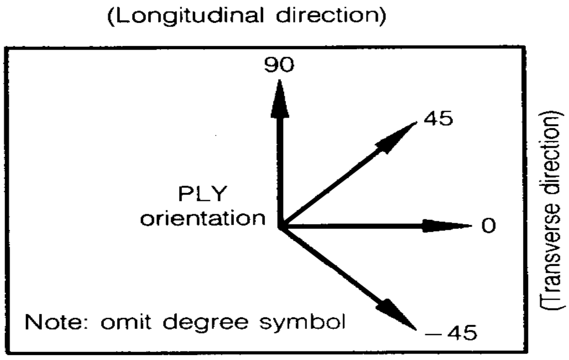

Figure 3: Solid Shim (Laminated Composite Pre-Peg Layup Direction)

Table 2: Types of Shims used During Assembly

S. No	Types of Shims	Shims Material
1.	Liquid shim	HYSOL934 & Al powder
2.	Solid shims	
3.	Metallic	Aluminium alloy, Titanium& Stainless steel,
4.	Pre-cured composite Laminate	Made from UD & BD pre-pregs
5.	Laminated *(Peel able)Shims	Laminated Titanium, stainless steel &Kapton shims
6.	Mouldable shims	Cast –in –place plastic

* Not in present scope of the study

Pre-cured composite laminate shown in table 2 at s.no.2II is used presently in aircraft manufacturing and this paper also discusses the same material shim is being used. Laminated and Mouldable shims are also used as per literature but specific usage on aircraft is not known. The usage on primary integral fuel tank wing structure is limited to pre-cured laminated shims made by AS4 composite material.

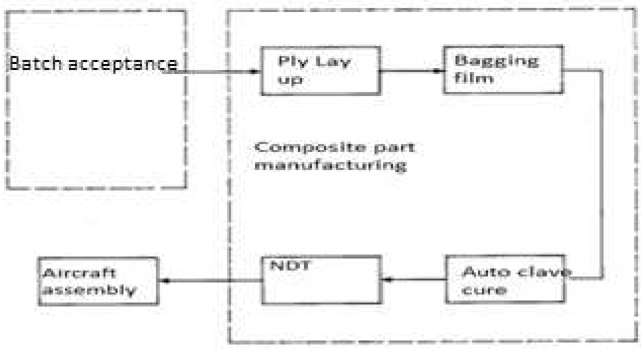

Figure 4: Composite Part Manufacturing Process

Figure 5 shows the male and female mold used for composite parts manufacturing and both processes have got pros and cons. However, Female mold process is used to manufacture spar shown in figure 6.

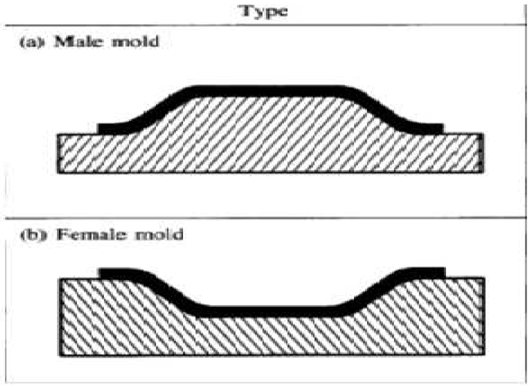

Figure 5: Moulding Tool of Composite Parts

Table 3: Handling and Performance Properties of Liquid Shim Material

S.no	Properties	HYSOL EA934NA & Al powder
a.	Color of mix	grey
b.	Mixing ratio	100:33:50
c.	Pot life @25C	40 mints
d.	Density of mix	1.36
e.	Cure Details	8 hrs at RT
Tensile Lap shear strength(MPA),tested as per ASTM D 1002 after curing for 7 days@32deg C		
a.	Test temp	21.4
b.	Immersion in water	24.1(30 days duration)
c	Immersion in Iso-propyl Alcohol	22.7(7 days duration)
d	Immersion in Hydraulic oil	24.1(7 days duration)
e.	Immersion in JP-4 fuel	24.1(7 days duration)
Tensile Lap shear strength(Mpa), deg C is omitted		

The cured liquid shim prepared out of Hysol 934 system shows the satisfactory result as a test conducted mentioned in Table 3.

Gaps are measured and accordingly, shims are used and details as below

Table 4: Model for Shim's Selection after Gap Measurement

S. No	Measured Gaps	Shims thickness
1.	Less or equal 0.2mm	Nil
2.	More than 0.2 till 0.8mm	Only Liquid shim
3.	More than 0.8	Solid shim

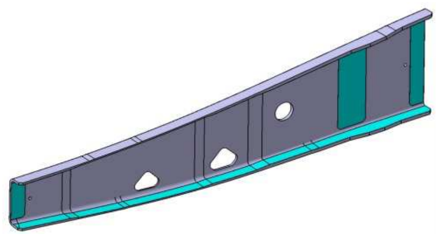

Figure 6: Spar, Wing Assembly Part on which Contour Measured at Six Places

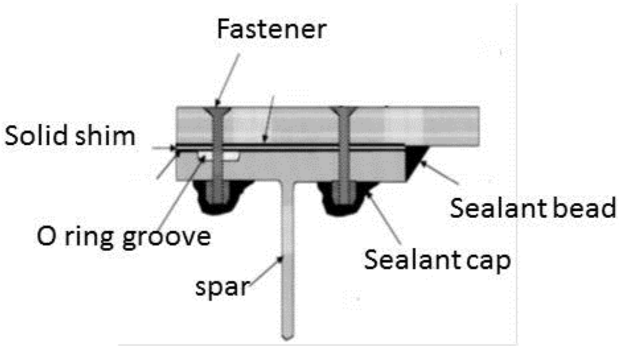

Figure: 7 Assembly Showing Shims and Fasteners

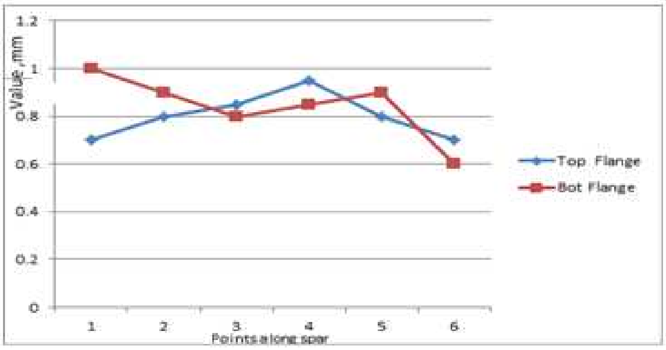

Figure 8: Measured Gaps of Top and Bottom Flange of Spar when Assembled with Skin

RESULTS AND DISCUSSIONS

Gaps between the interface of spar and wing skins at top and bottom flanges at six points vary from 0.8 to 1.2 mm. The shim gap at the top flange is less compared to bottom flanges. The selected spar is having about 0.5 -meter length and has a curved top and bottom surfaces. Composites parts post de-molding operation show variation in outer contour tolerance on top and bottom flange. Data has been measured by CMM, when the spar is assembled with the skin during assembly, it is forming a gap and gap value also is shown in Figure.6. This gap is filled with liquid shim and solid shims based on gap thickness. After application of shims, the skin is removed from sub-structure and filed to make the smooth faying surface. The work content at the assembly time adds up considerably due to shims filing and shims preparation, which is under study to find ways to reduce time.

CONCLUSIONS

The current gap checking and shimming process during wing structure build needs process improvement to reduce Gap measurement, shim preparation and installation time in order to ramp up production by 25-30 %. This study shows that C-section spar part as shown in Figure 6, contour on top and bottom flange is varying up to 1mm when the spar is assembled with the skin during assembly stage then further gaps are added up. Spar studied is made by Female tool, shown in Figure 5 (b) but still, there is a variation on the flange which is inherent of the cured composite parts. Parts during CMM inspection gives an indication for the shim requirement, which needs to be addressed before the assembly stage itself. Based on the literature survey and manufacturing study, this study concludes that the opportunity exists to look for standard shims by further analysis of gaps and part geometry.

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